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STATEMENT OF PROGRESS:

Starr County Saline Soil Study

A manuscript has been prepared entitled "Distiguishing Saline from Non-Saline Rangelands with SKYLAB Imagery," by J. H. Everitt, A. H. Gerbermann, and J. A. Cuellar. It is proposed for publication in the Journal of Range Management. The "Highlight" of the paper follows, and a copy of the manuscript is attached.

Highlight: A flight line in Starr County, Texas, was used to test the feasibility of distinguishing saline from non-saline rangelands using very small-scale (1:3,000,000) SKYLAB satellite imagery. Film optical density readings were made on six different films (four black-and-white, one conventional color, and one color infrared) using various film/filter combinations. Automated differentiation between saline and non-saline rangelands was possible through the use of microdensitometry on black-and-white SKYLAB imagery.

DISTINGUISHING SALINE FROM NON-SALINE RANGELANDS WITH SKYLAB IMAGERY

J. H. Everitt, A. H. Gerbermann,
and J. A. Cuellar

Many soils in arid areas of the world are affected by salinity. Detection of these saline areas is of considerable importance to range scientists and wildland ecologists involved in the use and management of these soils.

Rangeland holdings are often so large and inaccessible that photography or other imagery are necessary to determine their characteristics and extent. The application of remote sensing to rangeland assessment is well established (Colwell, 1969; Johnson, 1969; Poulton, 1970).

Several investigators have shown that classification of rangelands could be accomplished with both color and color infrared photography (Carneggie et al., 1967; Driscoll, 1971; Francis, 1970). Earth Resources Technology Satellite (LANDSAT-1) imagery has been used for mapping vegetation and monitoring changes in the range resources (Bentley, 1973; Seevers et al., 1973; Tueller et al., 1973).

Aldrich (1971) used microdensitometry to identify various land units on Apollo 9 color infrared photos. Driscoll et al. (1974) showed the usefulness of microdensitometry to identify plant communities and components on color infrared aerial photos. In this paper we present the feasibility of using microdensitometry on SKYLAB imagery for distinguishing saline from non-saline rangelands in Starr County, Texas.

STUDY AREA AND METHODS

This study was conducted along a 15-mile north to south flight line in Starr County, Texas (Figure 1). The southern end of this line is located approximately 4 miles north of Roma. Gould (1969) included this area in the South Texas Plains vegetational area.

The land use along this flight line is rangeland. The topography is nearly level to gently undulating. A few areas are hilly and broken by caliche and gravel ridges.

The climate of this area is mild with short winters and relatively warm temperatures throughout the year. Summer temperatures and evaporation rates are high. Average annual rainfall is approximately 17.3 inches. Heaviest rains occur in May and September (Texas Almanac, 1974). There are often months when no precipitation occurs.

Thompson et al. (1972) named seven soil types and six range sites for this study area:

Soil Types	Range Site
Catarina soils	Saline clay (saline)
Copita fine sandy loam	Gray sandy loam (non-saline)
Garceno clay loam	Clay loam (non-saline)
Maverick soils, eroded	Rolling hardland (saline)
Montell clay, saline	Saline clay (saline)
Ramadero loam	Ramadero (non-saline)
Zapata soils	Shallow ridge (non-saline)

Field Methods

Three replications each of the seven soil types were chosen on the basis of their area on the ground being large enough to be discernible on spacecraft imagery. Thus, a total of 21 sample sites were chosen along the flight line.

Ground truth data were collected for each of the sample sites. Soil samples were taken from each site in order to determine the electrical conductivity (EC_e) of each soil type. Samples were taken at soil depths of 0 to 15, 15 to 30, 30 to 45, and 45 to 60 cm. The majority (16) of the 21 sample sites were "brush-infested native rangeland;" however, the brush had been partially controlled on five sites (2 gray sandy loam, 2 clay loam, 1 Ramadero) and the range reseeded to "introduced grasses." Vegetational composition of the different range sites was determined by the line transect method (Canfield, 1941) for woody plants, and the point frame method (Tothill and Peterson, 1962) for herbaceous plants. The Catarina soils and Montell clay soils are saline soils that have the same associated range site (Saline clay site). However, since these were two separate soil types among the sample sites, they were treated as separate range sites in describing their botanical composition.

Laboratory Methods

Electrical conductivity (EC_e) of the saturated soil extracts of each of the seven soil types was performed according to the method of Richards (1954).

The SKYLAB imagery used in this study was exposed at 2:45 p.m. central standard time on May 30, 1973, at a scale of 1:3,000,000. Table 1 lists the flim/filter combinations and the wavelengths used in this study.

Film density readings were made with a Joyce Loebl and Company [1] (England) microdensitometer equipped with an automatic scanning attachment made by Tech/Ops (Burlington, Mass., USA). Density readings were made on the films listed in Table 1. Color density readings were made with four different lights: white (no filter), red (Wratten 92 filter), green (Wratten 93 filter), and blue (Wratten 94 filter). Black-and-white film density readings were made with white light only. Each density reading represents the density of 0.0015 sq. mm. of film, and readings were made at 100 per 2.54 mm. on the films.

The various sample sites were located on an isodensitracing (gray map) of each film type.

Density readings were grouped by soil type and associated range site, color light density, and film type, and read into a computer by sampling sites. To eliminate unusually high or low density readings caused by clouds or manmade objects, a mean and standard deviation were calculated and the computer then eliminated all density readings outside of the interval of the mean ± one standard deviation and then recalculated a mean for each sample site.

The mean density readings for each sampling site were used as replications for each soil type and range site. For color and color infrared film, an analysis of variance was calculated for each color light density; one analysis of variance was calculated for each of the black-and-white films.

Duncan's Multiple Range Test was used to make all possible mean comparisons ($P < .05$) among soil types and their associated range sites.

RESULTS AND DISCUSSION

Ground Truth Data

Table 2 shows the major grasses and woody plants found on the study area and the seven range sites on which they dominate. Botanical composition among these seven sites was similar in many instances, as many of the same grasses and woody plants were dominant on both saline and non-saline range sites. However, a few species such as saladillo (*Varilla texana*), guapilla (*Hechtia glomerata*), dwarf screwbean (*Prosopis reptans*), curly mesquite grass (*Hilaria belangeri*), and buffalo grass (*Buchloe dactyloides*) were found only on the saline range sites.

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[1] Mention of company or trademark is for the readers' benefit and does not constitute endorsement of a particular product by the U. S. Department of Agriculture over others that may be commercially available.

Although many of the same species occur on both saline and non-saline sites, the growth forms and herbage biomass production varies considerably between sites. The grass composition on the saline sites is dominated by shallow-rooted, sod grasses and other short grasses, whereas on the non-saline sites there is an inter-mixture of short and mid-grass species. The appreciable concentration of soluble salts in the upper soil profiles of the saline range sites limits plant growth (Davis and Spicer, 1965; Fanning et al., 1965). These saline sites are characterized by having large bare soil areas or "slicks" and surface deposits of sodium salts (Figure 2). These conditions lead to appreciably lower amounts of herbaceous biomass on these sites than on the non-saline sites (Fanning et al., 1965; Thompson et al., 1972). The high concentrations of these salts limits the growth form of the woody species to a "stunted" type on saline sites. This is evident when Figure 2 is compared with Figure 3. This "stunted" or low brush type is generally comprised of a comparatively low woody plant canopy cover with woody plants less than 5 ft tall, whereas on the non-saline range sites the woody plant canopy covers are more dense with taller and more spreading plants.

The EC_e values of the soil extracts from the seven different soil types and their associated range sites are presented in Table 3. These EC_e values relate salt concentration in the soil to the effect on plant growth. Commonly used guides proposed by the United States Salinity Laboratory staff (Richards, 1954) are: salt concentration greater than 4.0 mmhos/cm limits production of most forage crops; above 8.0 mmhos/cm, only moderately salt-tolerant species grow well; and above 12.0 mmhos/cm, only the most salt-tolerant species survive. Based on these guide lines, the two saline clay range sites (Catarina soils and Montell clay, saline) and the rolling hardland range site (Maverick soils, eroded) have EC_e values in the ranges of high salinity. The low EC_e values of the other four range sites (clay loam, gray sandy loam, Ramadero, and shallow ridge) places them in the non-saline category.

<u>Film Density Results</u>

<u>Black-and-White Films</u>: Table 3 shows statistically significant differences (Duncan's Multiple Range Test) among the seven range sites for mean optical density readings taken with white light on three black-and-white films [SO-022 (0.50 - 0.60 μm), SO-022 (0.60 - 0.70 μm), and EK-2424 (0.70 - 0.80 μm)]. Duncan's Test sorted these seven sites into essentially two main groups on each film. For the two films SO-022 (0.50 - 0.60 μm) and SO-022 (0.60 - 0.70 μm) the means followed by the common letter 'a' represent those range sites with the highest salinity and film density, and the means followed by the common letter 'c' were lowest in salinity and film density. However, the division between range sites with low and high salinity was not absolute as evidenced by means followed by the common letter 'b'. For the infrared black-and-white film

[EK-2424 (0.70 - 0.80 μm)], the means followed by the common letter 'a' represent those range sites with the highest salinity and lowest film density, while those means followed by the common letter 'c' were lowest in salinity and highest in film density. Some overlap between range sites with low and high salinity is evidenced by the means followed by the common letter 'b'.

No significant difference ($P < .05$) was found among mean optical density readings for the seven range sites on infrared black-and-white film [EK-2424 (0.80 - 0.90 μm)]. This film appeared to be over-exposed and therefore the data are not presented.

Saline range sites [saline clay (Catarina soils), saline clay (Montell clay, saline soils), and rolling hardland] could be distinguished from non-saline range sites (gray sandy loam, clay loam, Ramadero, and shallow ridge) with microdensitometry on black-and-white films exposed in the 0.50 - 0.60, 0.60 - 0.70, and 0.70 - 0.80 μm wavelengths. Although complete separation of all saline sites from all non-saline sites could not be accomplished on any of the three black-and-white films (Table 3), the same separation of the seven sites into two main groups was accomplished on all films. Black-and-white film SO-022 (0.60 - 0.70 μm) had the least overlap between range sites with low and high salinity. Here, five absolute separations were achieved among the seven sites. On black-and-white film SO-022 (0.50 - 0.60 μm) and infrared black-and-white film EK-2424 (0.70 - 0.80 μm) four absolute separations were accomplished on each film.

Mean optical density differences among saline and non-saline rangelands is believed to be attributed to the high occurrence of bare soil areas on saline range sites. These bare soil areas caused higher optical density readings for saline range sites on black-and-white films exposed in the 0.50 - 0.60 μm and 0.60 - 0.70 μm wavelengths, and lower optical density readings for the black-and-white film exposed in the 0.70 - 0.80 μm wavelength.

Color and Color Infrared Films: Table 4 shows statistically significant differences (Duncan's Multiple Range Test) among the seven range sites for mean optical density readings taken with white, red, green, and blue light for color film SO-356 (0.40 - 0.70 μm) and color infrared film EK-2443 (0.50 - 0.88 μm). However, only white light on color film SO-356 showed a partial separation among saline and non-saline range sites. On this film those means followed by the common letter 'a' represent those range sites with the highest salinity and lowest film density. Those means followed by the common letters 'd' and 'e' are non-saline range sites and of higher film density. The mean densities for all other film/filter combinations on color film SO-356 and color infrared film EK-2443 show statistical differences among range sites; however, no definite relationship can be established between film optical densities and range site salinity levels.

The microdensitometer could partially differentiate saline rangelands into one group on color film SO-356 (0.40 - 0.70 μm) with white light (Table 3); however, this was minimal. Other film/filter combinations on color film SO-356 and color infrared film EK-2443 (0.50 - 0.88 μm) showed no definite separation between saline and non-saline range sites.

Mean optical density readings on color and color infrared film showed differences among the various range sites. However, differentiation between saline and non-saline sites was minimal and no definite relationship could be made between film optical densities and range site salinity levels. Since differentiation between saline and non-saline range sites on color and color infrared film could not be accomplished, it is believed a film interaction exists, caused by various combinations of soil and vegetation reflectance. Therefore, further study on this interaction is deemed necessary.

CONCLUSIONS

This study shows that automated differentiation between saline and non-saline rangelands is possible through the use of microdensitometry on very small-scale (1:3,000,000) black-and-white SKYLAB satellite imagery.

ACKNOWLEDGMENTS

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Table 1. Film/filter combination and sensitive wavelength for the SKYLAB S-190A multispectral photographic camera sensor system.

Wavelength (μm)	Film	Filter (NASA designation)
0.50 - 0.60	Pan-X B & W (SO-022)	AA
0.60 - 0.70	Pan-X B & W (SO-022)	BB
0.70 - 0.80	IR B & W (EK-2424)	CC
0.80 - 0.90	IR B & W (EK-2424)	DD
0.50 - 0.88	IR Color (EK-2443)	EE
0.40 - 0.70	HI - RES color (SO 356)	FF

Table 2. Major woody plants and grasses found on the seven range sites along a flight line in Starr County, Texas, and the range sites on which they dominate.

Species[1]	Site[2]
Woody	
Acacia berlandieri Benth.	1,2,4,6,7
A. rigidula Benth.	1,2,4,5,6,7
Aloysia gratissima (Gill. & Hook.) Troncoso	3
Castela texana (T. & G.) Rose	1,2
Celtis pallida Torr.	5,6
Citharexylum spathulatum Moldenke & Lundell	5
Eysenhardtia texana Scheele	6,7
Forestiera angustifolia Torr.	6
Hechtia glomerata Zucc.	2
Jatropha dioica Cerv.	7
Karwinskia humboltiana (R. & S.) Zucc.	7
Krameria ramosissima (Gray) Wats.	7
Lantana macropoda Torr.	5
Leucophyllum frutescens (Berl.) I. M. Johnst.	5,7
Opuntia leptocaulis DC.	1,3,4,6
O. lindheimeri Engelm.	3,5
Pithcellobium flexicaule (Benth.) Coult.	5
Porlieria angustifolia (Engelm.) Gray	4,5,6
Prosopis glandulosa Torr.	2,3,4,5,6
P. reptans Benth.	3
Schaefferia cuneifolia Gray	5,7
Varilla texana Gray	1,2,3
Zanthoxylum fagara (L.) Sarg.	6
Ziziphus obtusifolia (T. & G.) Gary	1,2,3,4,5
Grasses	
Aristida purpurea Nutt.	1,2,3,4,5,6,7
Bouteloua trifida Thurb.	1,2,3,4,5,6,7
Buchloe dactyloides (Nutt.) Engelm.	2,3
Cenchrus ciliaris L.	4,5,6
Chloris cucullata Bisch.	5,6,7
Eragrostis curtipedicellata Buckl.	1,3,5,7
Hilaria belangeri (Steud.) Nash	1,2,3
Panicum hallii Vasey	5,6
Setaria texana W.H.P. Emery	4,5,6,7
Sporobolus cryptandrus (Torr.) Gray	5,6,7
S. pyramidatus (Lam.) Hitch c.	1,2,3
Trichloris pluriflora Fourn.	6
Tridens muticus (Torr.) Nash	1,4,5,7

[1] Plant names are according to Correll and Johnston (1970).

[2] Site 1 = rolling hardland; Site 2 = saline clay (Catarina soils); Site 3 = saline clay (Montell clay, saline); Site 4 = clay loam; Site 5 = gray sandy loam; Site 6 = Remadero; Site 7 = shallow ridge.

Table 3. Microdensitometer readings with white light on SO-022 (0.5-0.6 μm), SO-022 (0.6-0.7 μm), and EK-2424 (0.7-0.8 μm) aerial black-and-white films exposed on the SKYLAB S-190A multispectral photographic camera for seven range sites on a flight line in Starr County, Texas. EC_e values are expressed in millimhos/centimeter.

Range site	EC_e (mmhos/cm)	Film SO-022[1] (0.5-0.6 μm)	Film SO-022[1] (0.6-0.7 μm)	Film EK-2424[1] (0.7-0.8 μm)
Rolling hardland (Maverick soils, eroded)	6.4	79.64ab	72.12a	108.90ab
Saline clay (Catarina soils)	9.4	73.40ab	70.15a	107.81ab
Saline clay (Montell clay, saline)	12.6	84.31a	68.20ab	104.01a
Clay loam (Garceno clay loam)	0.9	64.38 bc	63.49 bc	123.98 c
Gray sandy loam (Copita fine sandy loam)	0.6	51.15 c	60.90 c	127.31 c
Ramadero (Ramadero loam)	0.6	54.58 c	60.87 c	124.46 c
Shallow ridge (Zapata soils)	0.6	53.22 c	58.33 c	120.05 bc

[1] Means followed by a common letter are not significantly different at the 5 percent probability level according to Duncan's Multiple Range Test.

Table 4. Microdensitometer readings with white, red, green, and blue lights on SO-356 (0.40-0.70 μm) aerial color and EK-2443 (0.50-0.88 μm) aerial color infrared films exposed on the SKYLAB S-190A multispectral photographic camera for seven range sites on a flight line in Starr County, Texas. EC_e values are expressed in millimhos/centimeter.

Range site	EC_e (mmhos/cm)	SO-356 Color Film (0.40-0.70 μm)				EK-2443 Color IR Film (0.50-0.88 μm)			
		White[1] light	Red[1] light	Green[1] light	Blue[1] light	White[1] light	Red[1] light	Green[1] light	Blue[1] light
Rolling hard-land (Maverick soils, eroded)	6.4	85.09a	81.88a	78.74a	61.48a	70.89a	102.66ab	79.72ab	47.58ab
Saline clay (Catarina soils)	9.4	102.32abc	93.55ab	92.39abc	78.25b	70.38a	97.08a	74.02a	41.44a
Saline clay (Montell clay, saline)	12.6	92.14ab	87.66ab	84.34ab	64.72a	81.85b	110.34bc	88.97bc	54.36bc
Clay loam (Garceno clay loam)	0.9	108.61bcd	95.18ab	92.10abc	78.17b	81.59b	112.75bc	89.81bc	54.17bc
Gray sandy loam (Copita fine sandy loam)	0.6	111.90cde	105.37bc	100.06bcd	82.12bc	85.89b	106.83ab	88.67bc	60.36cd
Ramadero (Ramadero loam)	0.6	129.50e	118.87c	109.55d	91.85c	82.75b	111.95bc	92.27c	57.90cd
Shallow ridge (Zapata soils)	0.6	123.17de	119.86c	108.35cd	85.54bc	90.84b	120.60c	99.04c	65.34d

[1] Means followed by a common letter are not significantly different at the 5 percent probability level according to Duncan's Multiple Range Test.

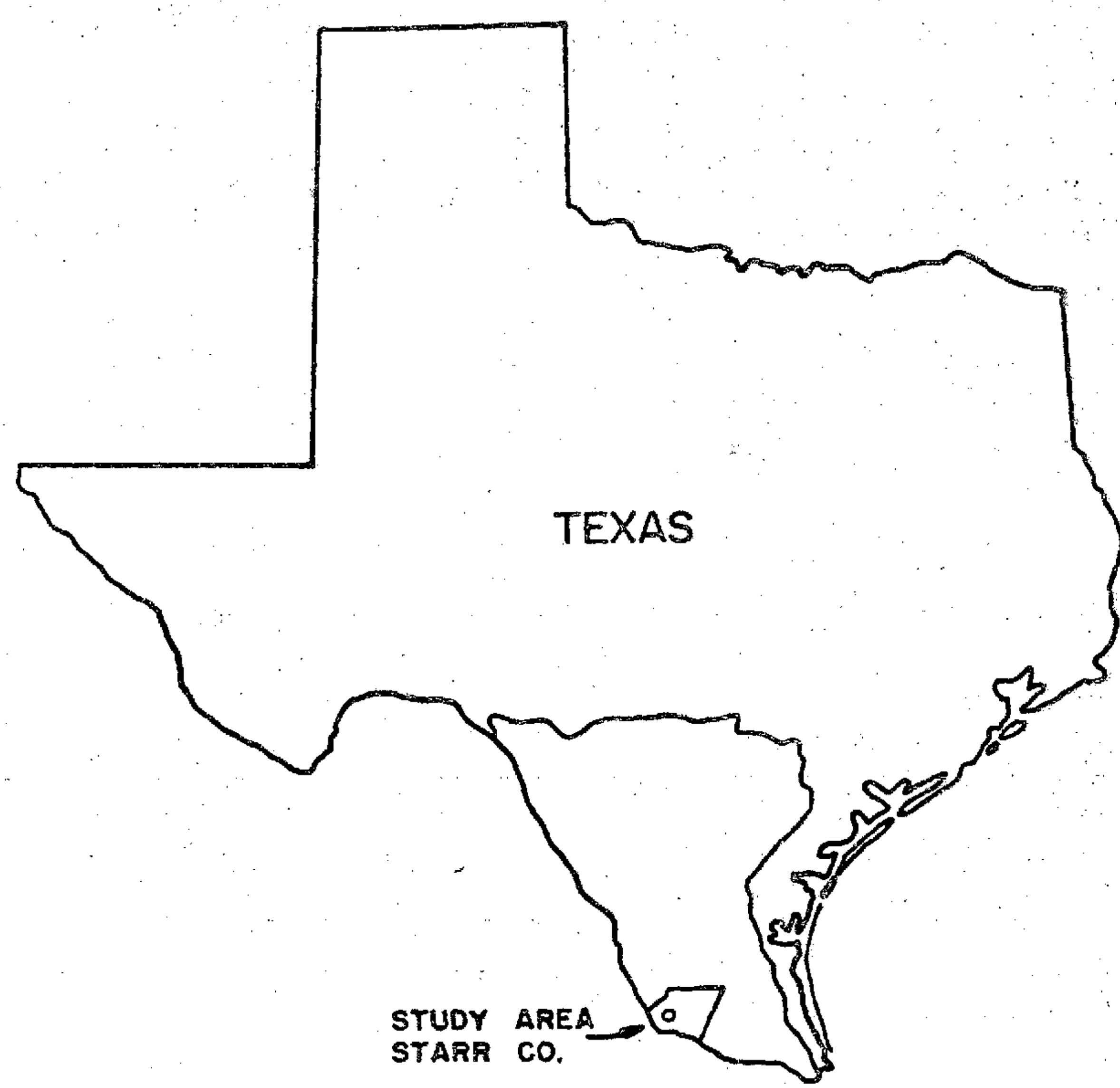

Fig. 1.--Location of study area in Starr County, Texas; South Texas Plains, hatched.

Fig. 2.--Photograph of saline clay range site.

Fig. 3.--Photograph of gray sandy loam range site.